Annals of Physical Medicine

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BRITISH ASSOCIATION OF PHYSICAL MEDICINE

July 1952

THE CONGRESS

ON the fourteenth of July the first International Congress of Physical Medicine to be held since 1938 will open in London. The honour of organizing the Congress has been conferred by the International Federation on the British Association of Physical Medicine. Deeply sensible of this honour, we tender our guests a cordial welcome to our country.

The Congress is long overdue, more especially as in the fourteen years since the last meeting Physical Medicine has expanded its scope and increased its reputation to a degree unequalled in its previous history. With its wide terms of reference, which include physical development, rehabilitation, and the use of physical methods in diagnosis and treatment, it represents one of the most important applications of modern science to the philosophy of healing. It is in a true sense social medicine.

An International Congress fulfils many useful functions: it encourages the exchange of ideas ; it enables friends in different countries to renew their friendship; it allows those taking part to make the acquaintance of many of whom they have heard but have never met. And there is another important function. A century ago General Grant in his inaugural address as President of the United States of America expressed his faith " That the Great Maker in His own good time would fulfil the purpose that all mankind would become one nation ". To further that ideal is the right mission of any International Health Congress, and it is particularly appropriate on the present occasion, for Physical Medicine is a discipline which aims, above all, to help human beings to achieve harmony with their surroundings.

THE INSIGNIA OF THE CONGRESS

THROUGH the great generosity of three benefactors, the following insignia have been presented to the International Congress of Physical Medicine :

1. Presidential Badge presented by Mr. Bernard Baruch in memory of his father, Dr. Simon Baruch. Designed by Helen Robinson (Newbury). Made by Fattorini & Sons (London).

2. Ceremonial Lamp presented by Lord Horder. Designed by C. J. Shiner (Birmingham), in collaboration with J. Francis Coote (London). Made by Blunt & Ray (London).

3. Gavel and Block presented by Mrs. Richard Kovacs in memory of her husband, Dr. Richard Kovacs.

Photographs of the Presidential Badge and of the Gavel and Block are included in this issue of the ANNALS; a photograph of the Ceremonial Lamp will appear in the October issue.

BRITISH ASSOCIATION OF PHYSICAL MEDICINE
ANNUAL MEETING

THE Annual Meeting of the British Association of Physical Medicine, which took place on April 25 and 26, 1952, was generally agreed to be the most successful meeting of its kind that the Association has held. Eighty members were present at the scientific sessions, and 90 members and guests at the dinner, over which Lord Horder presided. The Guests of Honour were as follows: The President of the Royal College of Surgeons and Lady Wakeley; the Chairman of Council of the Chartered Society of Physiotherapy and Mrs. Whillis; the Vice-Chairman of the Council of the Chartered Society of Physiotherapy, Miss W. McAllister; and the Vice-Chairman of Council of the Association of Occupational Therapists, Miss Birkbeck.

At the Annual General Meeting the following were elected Officers of the Association:

President: THE RIGHT HON. LORD HORDER, G.C.V.O.
Vice-President: DR. P. BAUWENS
Honorary Secretary: DR. A. C. BOYLE
Honorary Treasurer: DR. W. S. TEGNER
Honorary Editor: DR. HUGH BURT

The scientific papers presented at the meeting are fully reported in this issue of the ANNALS, and the discussion will appear in the October number.

PRESIDENTIAL BADGE.

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GAVEL AND BLOCK.

POSTURAL HOMŒOSTASIS*

By WILFRED BARLOW

THIS paper gives a short account of a study in postural re-education which I have recently completed. The subjects came from one of the London Voice and Drama Colleges. A two-sided investigation was carried out: (1) Sheldon " somatotype " photographs were taken before and after re-education; and (2) a behavioural report on the students was prepared by two professors in charge of them.

Method of Re-education Employed

The typical Pavlov conditioned reflex is well known. The presentation of food along with the ringing of a bell is followed by salivation; eventually salivation is produced by ringing the bell alone without the food. The new response is termed a *conditioned response* and the bell is called a *conditioned stimulus.*

Konorski (1948), the most prominent worker in this field at present, has described a second type of conditioned reflex: the " Konorski Type 2 reflex ", as it is known. His description of it is: " If we subject to a conditioning procedure of the first type [the classical Pavlov type] a compound of stimuli consisting of an exteroceptive and proprioceptive stimulus, in which the proprioceptive stimulus constitutes an indispensable complement to the conditioned compound, then the exteroceptive stimulus begins to evoke the movement generating the proprioceptive stimulus." This sounds a little involved, but what it amounts to is that if you associate a given degree of muscle tension (and its associated feeling) with an external stimulus, in time this given tensional balance is produced by the external stimulus alone.

In the experiment which I have carried out this principle was employed. The other novel aspect of the approach was that I used a *verbal* stimulus as the exteroceptive stimulus, first in the form of a vocalized word of command, and eventually as a subvocalized command given by the subject. This procedure has been used and described by Hudgins (1933) in a different context, notably in the conditioning of pupillary contractions, and it was first employed in connexion with the re-education of tensional balance by Alexander (1932).

My subjects are taught to project a series of verbal directions, and these are linked up for them with an improved postural reaction which I

* Paper read at the Annual Meeting of the British Association of Physical Medicine on April 26, 1952.

describe later. In a relatively short period of time the subject is able to evoke at will the improved manner of using the body. As he becomes familiar with the process, a new body image is built up, a new standard against which he can assess his deviations from postural stability.

What do we Mean by a Postural Standard ?

Before describing the actual experiment, I should like to discuss briefly what is meant by a postural standard.

The objection to most postural standards is that they are fixed. They do not take into account Sir Henry Head's view that, " by means of perpetual alteration in position, we are always building up a postural model of ourselves which constantly changes " (1920).

The concept of the postural model or body image can be understood most clearly in terms of what is known as " feed-back ". I expect most of us object to the facile use of this term of neurology, but it is relevant to the present discussion. The typical feed-back model of the central nervous system is shown simply in Fig. 1. Here we are concerned with a

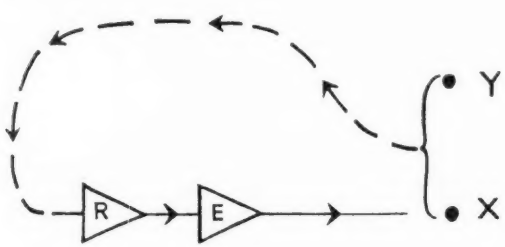


FIG. 1.

goal-seeking movement (or communication), in which X is the subject's current state and Y is the state of subject + environment which we call the goal. There must be an effector, E, capable of altering the state X, and this must be controlled by a receptor element, R, which is capable of receiving information and computing it against its previously stored experience. Information about the magnitude of XY must be fed back from the field of activity to R, thence to give rise to activity in E leading to modification of the movement XY. Numbers of mechanical devices use this procedure—for example, the thermostat.

When a thermostat corrects an error it makes a new one, and this, too, it corrects by making a further but smaller error. Oscillation occurs if the self-correcting mechanism overshoots its mark. The thermostat is,

in fact, in a state of steady motion, a state described by Cannon in 1926 as homœostasis—in which term he included the *processes* leading to a state of steady motion. The state of steady motion is best described by analogy—the top spinning on a vertical axis, the juggler balancing a number of objects on top of a pole. Riding a bicycle is another example. When the rider falls slightly to the right, he turns his front wheel to the right, which stops his fall but leads to his being thrown over on the left. This he corrects by turning his wheel to the left.

I should like to suggest the use of the term " postural homœostasis " to denote the state of steady motion which underlies all voluntary movement. Walshe (1951), in describing this recently, has pointed out that oscillation is characteristic of all voluntary activity. Postural homœostasis in the intact organism is effected by feed-back from the eyes, the muscles, and the labyrinth, and the information which is fed back is assessed against the postural model—R in the diagram. During movement, disequilibrium signals are generated in the receptor R by incoming stimuli, causing activity through the effector E until there is a sufficient degree of resemblance between the incoming pattern and the postural model. When the organism is adapting itself to stress it resumes its state of steady motion by a process of feed-back, and it is therefore imperative that the postural model should be adequate. The subject was first introduced in this way by Ashby in 1940 with his paper " Adaptiveness and Equilibrium ", and later by Norbert Wiener (1943).

Postural defects are very common, being present in between 70% and 80% of adolescents and increasing with age. Postural homœostasis is, in my opinion, primarily dependent on the correct equilibration of the head–neck relationship. In an observation (1946) on 316 male and 45 female subjects in the Army, I found that in 97·5% there was interference with the head–neck relationship during certain voluntary movements, and, further, that because of inadequate feed-back the subjects were unaware of this interference and could not correct it voluntarily. This pointed to the need for a conditioning procedure such as I have described—a Konorski Type 2 procedure—if the subjects were to build up an adequate postural model and not interfere with their postural homœostasis when they reacted and adapted themselves to outside stimuli and stresses.

The Experiment

During the last two years a group of 50 students under two professors from a London Voice and Drama College have volunteered as subjects, and they were re-educated in the manner stated. After the experiment had been going on for some time, Dr. J. M. Tanner offered me facilities to assess progress by means of Sheldon photography, and this was carried out on 20 subjects.

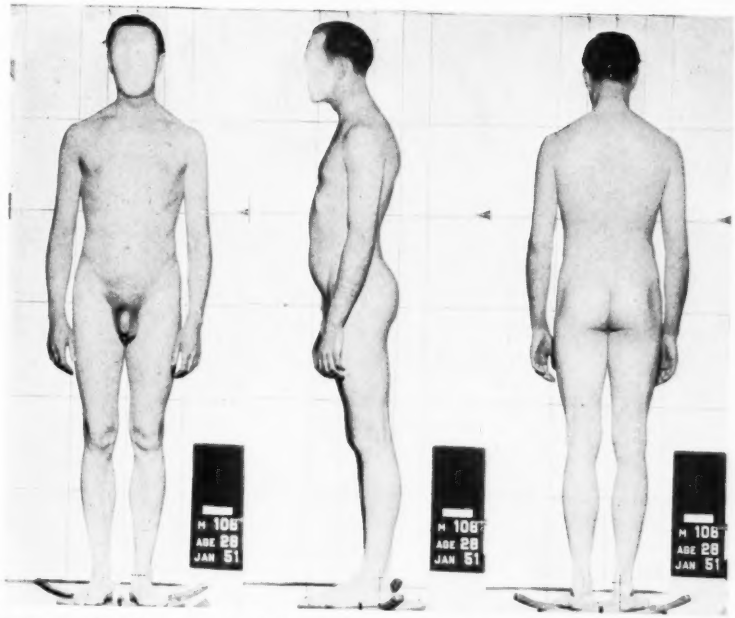
There are considerable limitations to assessing postural homœostasis by means of single photographs. A state of steady motion cannot be pinned down like a butterfly in a collector's cabinet. It would be fairly easy to give a misleading impression by a process of carefully selected photographs, and for this reason all the photography was carried out by Dr. Tanner as a completely disinterested observer. He adopted the same procedure in posing the subjects as he adopts in the large-scale somatotyping work which he is engaged on.

Two photographs were taken each time—a " loose " photograph in which the subject was told to stand comfortably, and a " standard " photograph posed by Dr. Tanner as already described by him (1950). From the point of view of homœostasis and reaction to stress, the situation is a good stress situation, as the subjects are taken very rapidly under hospital conditions and the women have the added stress of being completely nude. The subject stands on a turntable which can be turned through three planes. The feet are placed in special slots to ensure an identical position each time, and the grid at the back is in a fixed position.

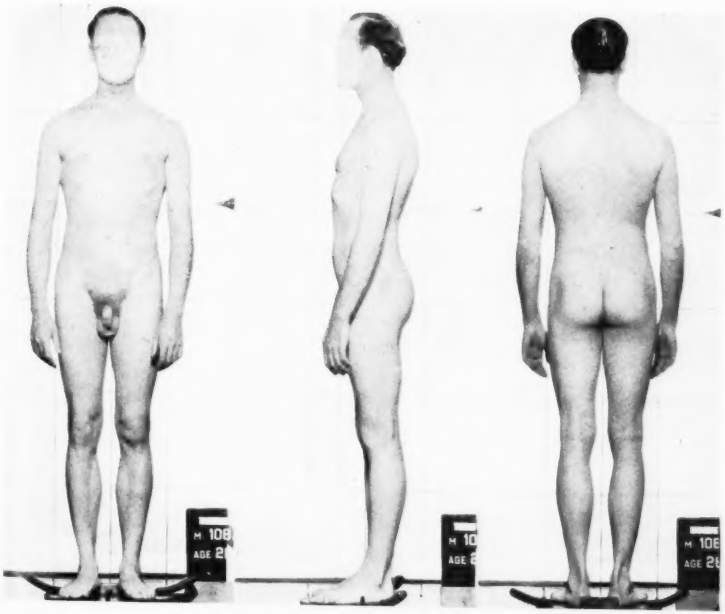
Plate IA is a typical " loose " picture before re-education. The subject is a student who before taking up stage work was a prominent athlete and a physical training instructor. In spite of this he exhibited quite definite postural defects which were interfering with his stage movements. In particular there is a considerable lordosis of the back, measuring nearly three lines against the grid, with a corresponding protrusion of the abdomen. The head is poked forward and the general attitude, along with the facial expression, was one of slump and depression. He had had a bad knocking about in a submarine explosion during the war, and was considered difficult by his teachers. Plate IB shows the same student after re-education. The most obvious changes are in the position of the back and of the abdomen, and the head axis is now quite good. The improvement in posture was accompanied by a general improvement in his work.

In Plate IIA is a voice student who was sent because of constant low back pain and because of extreme unpredictability of performance, good and bad days alternating for no apparent reason. She had just failed her audition for a leading opera company. In particular she had a bad twist of her left shoulder and side, which is apparent. It was interesting that in going for a high note she always accentuated the postural mistake on the left side, rotating round as she strained for the note. This was aesthetically unsatisfactory and interfered with her voice production. Her postural model was inadequate in that she was quite unaware of her postural mistakes and could not correct them. When she was corrected she felt crooked. The face had an expression of timidity. Plate IIB shows her after re-education. She has lost the rotary twist on the left side, and the tension in the trapezii is much less. Her low back pain has

PLATE I.



A, Before re-education. Note lumbar lordosis, protruding abdomen, and head poked forward.



B, After re-education.

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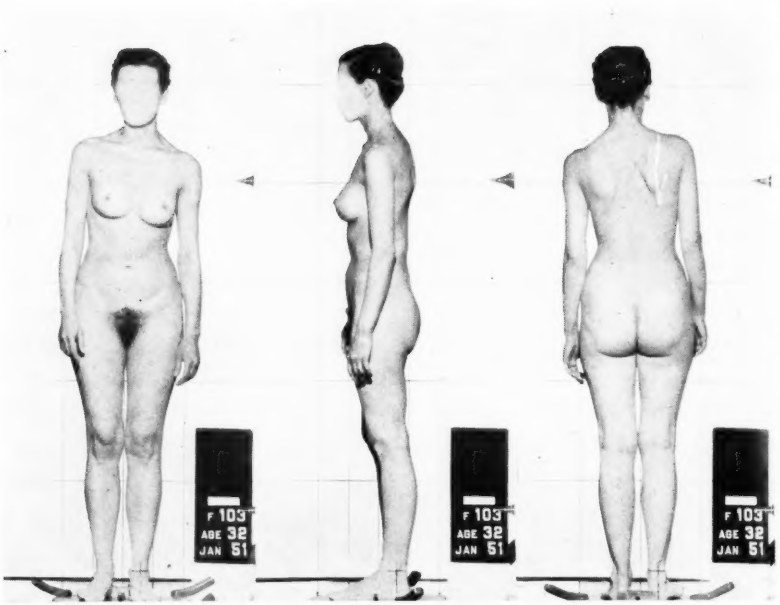
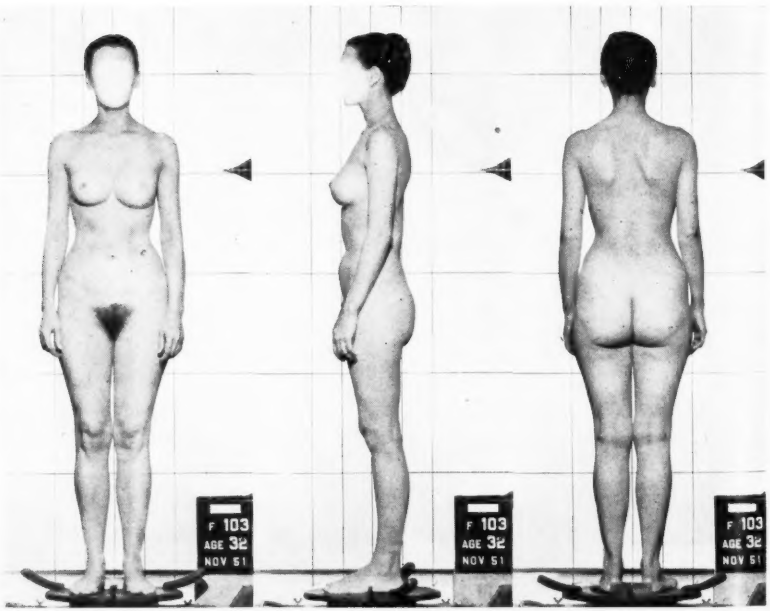
PLATE II.

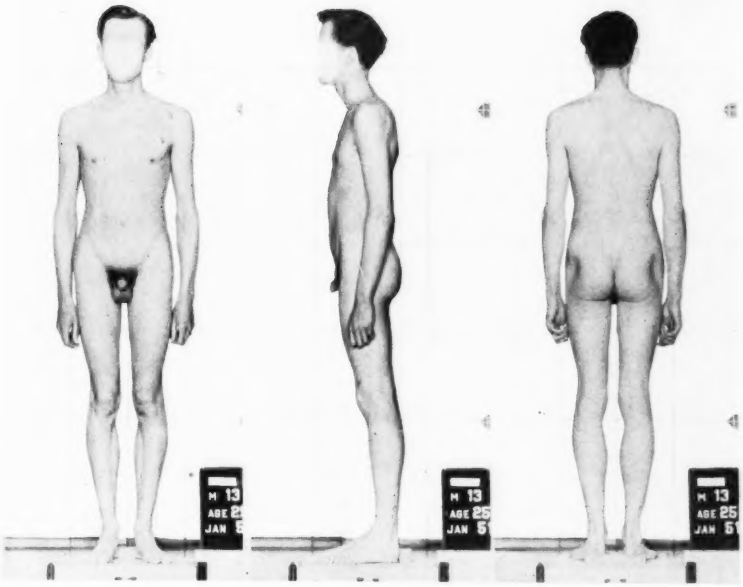


A, Before re-education. Note depressed left shoulder, tension in trapezii.

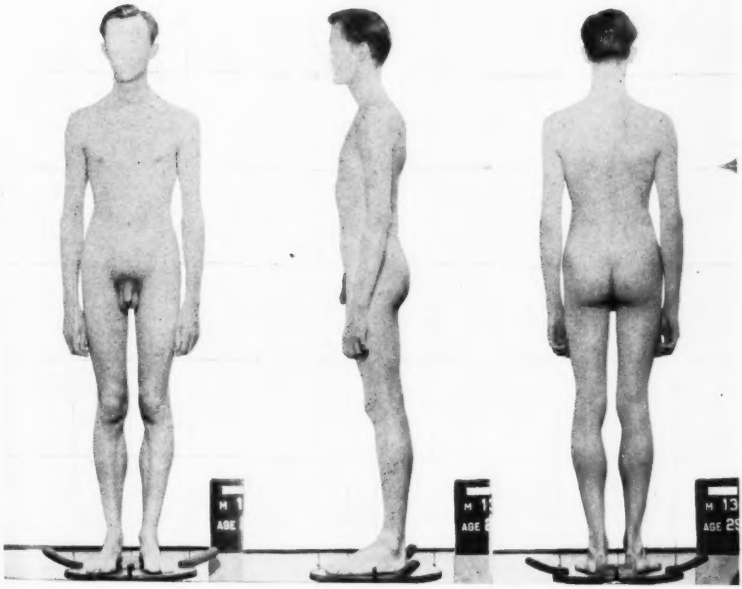


B, After re-education. Improved left shoulder, but scapulae still too prominent.

PLATE III.

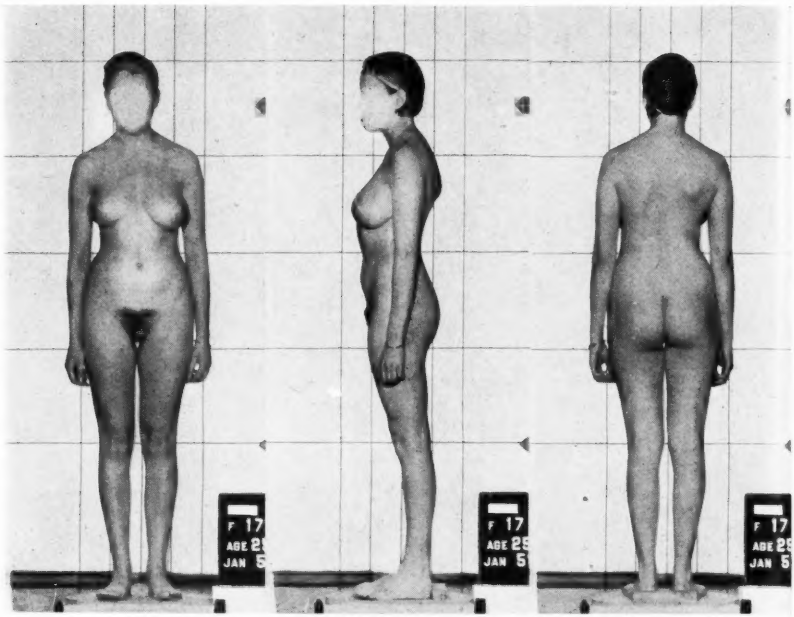


A, Before re-education. Note head-retraction and gluteal tension.

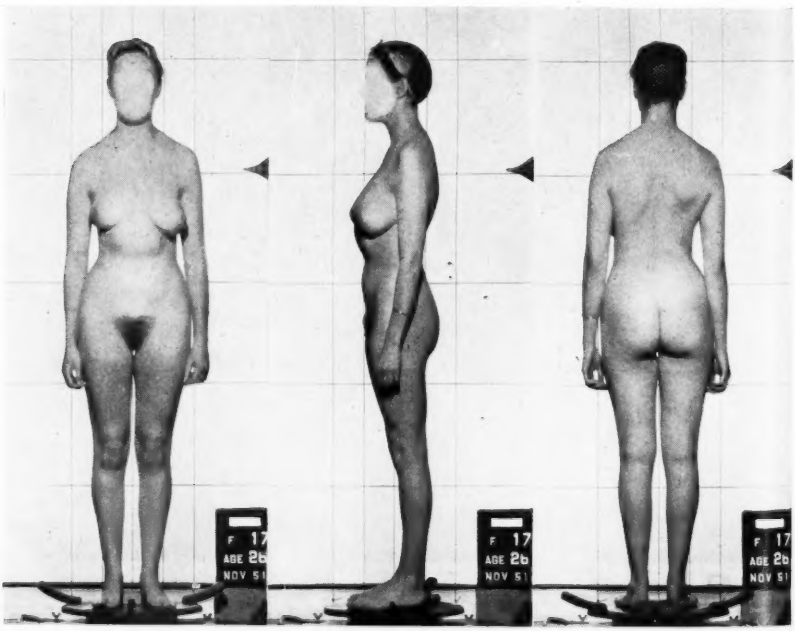


B, After re-education. General over-all impression much relaxed. Head position improved.

PLATE IV.

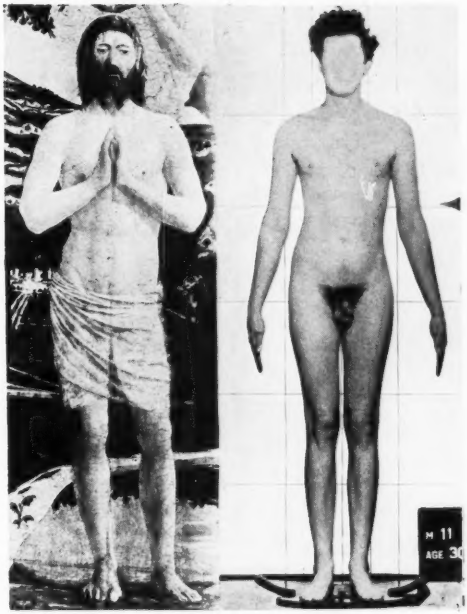


A, Before re-education. Note scoliosis and dorsal kyphosis.



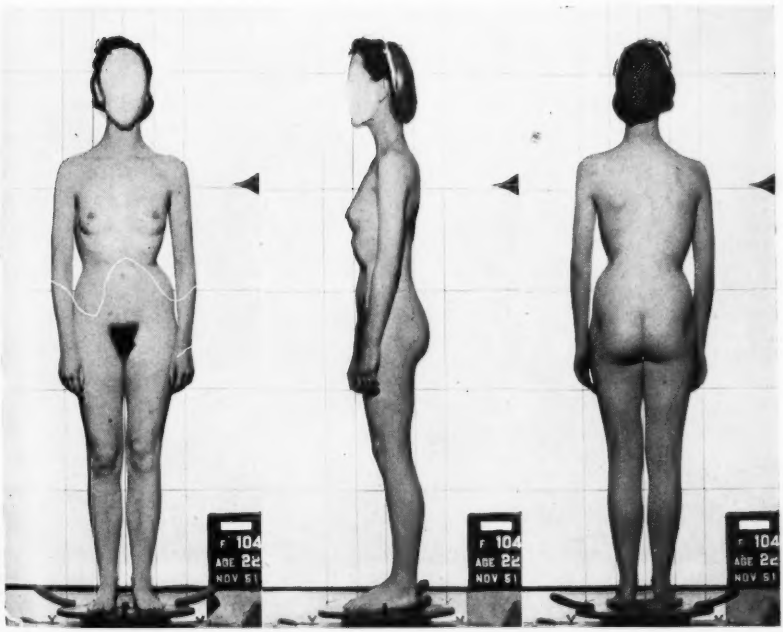
B, After re-education. Improvement in scoliosis and kyphosis.

PLATE V.



Left: Figure from painting by Piero della Francesca.
Right: Note similar twist of right side of pelvis.

PLATE VI.



Case of scoliosis after re-education. " Loose " unposed picture.

gone and has not returned for nine months. She took her audition again and was accepted.

Plate IIIA shows a male student who had suicidal tendencies, with a record of three attempted suicides. It demonstrates very clearly the head retraction, which is one of the most constant forms of interference with the head–neck relationship. The face had a hopeless expression of dependence: the whole attitude of the body was one of submission and delayed development. He is a Sheldon 235, very high in cerebrotonia, the artistic component. Plate IIIB shows him after two months' re-education. The head–neck relativity is now approximating to what it should be. It is interesting to see the lessening of tension in the buttocks. He previously suffered from regular migrainous headaches, but has been free from these for about six months. Such headaches arising from the head musculature are a common feature in anxiety states, and even when they do not originate in this way they are often perpetuated by a secondary spasm of the neck musculature, which the subject is unable to release without training.

Plate IVA shows a young woman with scoliosis who had had a great deal of posture therapy in the past. During re-education it came out that when she was at school she cultivated a deliberate stoop in order to hide her large breasts, which the other girls laughed at. Plate IVB shows her after re-education. Many postural defects occur through the perpetuation of some bio-social attitude—perhaps in imitation of a parent or teacher, or else in response to some idea of the sort of role which ought to be expressed when communicating with others. The prevailing fashions of the age play a considerable part. The correct use of the head–neck relationship seems to approximate to the classical conceptions of early Greek sculptors. In later Greco-Roman sculpture a laxness creeps in, and it is almost one of the hallmarks of Romantic art for the head–neck relationship to be distorted. The pre-Raphaelites are an obvious example.

The inclusion of Plate V may seem a little surprising, but it is of interest in this respect. It is of a fairly well-known art critic who was taking lessons from me. After a certain amount of re-education he brought me a reproduction of a picture by Piero della Francesca, the subject of which he considered to have a perfect stance. It will be obvious that the figure in the reproduction has almost the same marked rotary defect of the right side of the pelvis. This illustrates the pervasive influence of the body image even in our value judgments. The torsion of the hip shown is not a temporary pose, but is always present, although it may have started as a temporary pose.

Plate VI shows another young woman with scoliosis who in this case had been in a plaster bed for six months. She had been discharged from the Royal National Orthopaedic Hospital and told that nothing more

could be done. Their records say she had a fixed scoliosis with rotation. She had a lovely singing voice, but she had to hold on to a support while she sang. She wished to be an opera singer, but had failed her audition for entrance into an opera school before coming to me. Unfortunately no preliminary picture was taken, but the good result of re-education can be seen in the plate, which is a loose unposed picture. After six months' re-education she passed her opera audition, and recently sang and acted in " La Bohème " without any noticeable defect of movement. I should like to stress again that the re-education is not done by physical exercises, but by means of a conditioning procedure which alters the body image and through it the capacity for postural homœostasis.

Behavioural Report

I think that the best way to present the results would be to give a report from the two professors who have watched the students' progress throughout.

The college at which the students work provides an excellent microcosm for the study of behaviour. Much of the work is taken up in presenting fortnightly performances of plays and operas, and there are regular examinations for various degrees. The students were originally sent to me because of various specific troubles—poor movement and stage expression, and minor medical disorders such as headaches and low back pain. In the experiment a large number of " normals " were sent. The professors in charge of the group are extremely experienced in their field and are examiners for the Associated Board of the Royal Schools of Music; their opinion is therefore a responsible one. The situation is excellent for investigating a new educational procedure, since to serve as a control there are numbers of other students who are not receiving this single additional form of instruction. While a statistician might like to see it all planned out a little more formally, there is a lot to be said for using a living situation such as this in which there are recognized standards, and in which experienced teachers are quick to notice changes and have a shrewd idea of how quickly students can be expected to get on. They have prepared the following short report:

In reporting on the progress of the 50 students we have sent you, it might be best first to outline our experience with other students before they came to you. We roughly classified students into three grades. First, there were those with natural grace and freedom of movement and expression, who made good strides in their three-year training. Secondly, there were those who seemed to make no progress at all, and even deteriorated, during their training. Thirdly, there was a large in-between group, who, while not having any obvious gross handicap, never somehow quite made the grade. Dramatic and operatic work makes considerable demands on the student. The opera student these days needs not only a highly skilled vocal technique, but dramatic imagination and ability to express mood, emotion, and character; he

also needs musicianship, presence of mind, and exceptional freedom and nimbleness of movement. During the training we gave them they did a great deal of mime and dancing, and in cases where specific muscular tensions were particularly noticeable they were given specific exercises.

It was, however, our experience that during performance none of this training made a difference to deeply ingrained habit patterns. Habitual patterns of tension were not usually apparent to the student, and in most cases the student would strenuously deny the suggestion that he was tensing his body unduly. Our failures were all, without exception, over-tense when on the stage, either in a specific part of their body or generally. Any attempt on their part to relax could not be carried out specifically during performance, but w. . interpreted as a collapse of the whole body. By our ordinary approach we had reached a point where we saw that these tensions were responsible for the lack of progress of second- and third-grade students, but we were unable to deal with them. It was this problem that led us to try out the procedure you describe.

It would take too long to go into individual case histories, but a few broad generalizations can be made.

1. In each case there has been a marked physical improvement, which was usually reflected vocally and dramatically. It was a revelation to discover that tricks of behaviour could be eliminated in a comparatively short space of time once the student learned to control his tensional balance from the head–neck region.

2. In all cases students since re-education are easier to teach, and can take and carry out stage directions with greater ease. The students seem to become aware of themselves in a new way. Each student reacted in a different characteristic way. For example, those who had been over-anxious to please authority discovered that they could be themselves with impunity, ceasing to be such model students, but becoming better performers.

One student, a girl hampered by angular stereotyped movements and a curiously " spinsterish " quality of personality, has acquired considerable warmth and gracefulness. Another, with originally a very mediocre " drawing-room " voice, is now considered by her original teachers and critics to have developed the qualities of voice and personality that go to make a really great singer.

3. The time it takes to get results varies greatly between one student and another. The utilization of the approach depends largely on the student himself.

4. Eight of the 50 students entered last year for a singing prize which is competed for by women singers every four years. It is open to all amateur and professional singers under 30 from anywhere in the British Isles, and is considered the highest achievement possible for students. The total entry was over 100. Six of the eight students reached the semi-final, in which there were 15 semi-finalists. This is quite out of proportion to what one might expect.

5. In our opinion, this approach is the best means we have yet encountered for solving the artist's problem of communication, and should form the basis of his training.

I have in addition prepared a questionnaire, which was given to some of the students who were photographed. Various psychologists to whom I have shown it say that it is an adequate questionnaire, but I gather that most of them would like to see Rorschach testing, personality inventory tests, and so on. From my own point of view, all the students expressed satisfaction with the procedure, and, in answer to specific questions, none of them saw how else they could deal with the sort of difficulties which they had realized clearly for the first time during re-education.

Dr. Tanner also made anthropometric measurements on the subjects he photographed. All the subjects, with one or two minor exceptions, show small but definite increases in standing height, sitting height, and shoulder width—the biacromial measurement. The increase in height and width which is brought about by stopping interference with postural

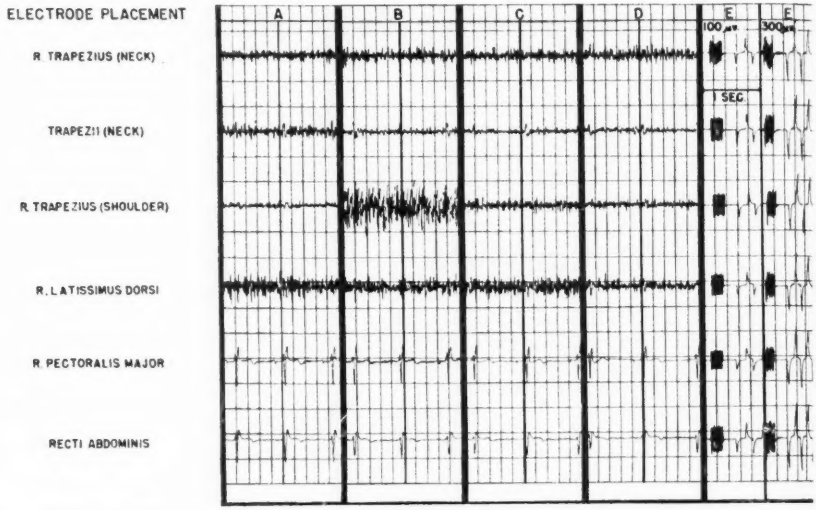


FIG. 2.

A is recorded in the habitual untrained sitting posture. In B the untrained subject is told to sit up straight by himself (140 cm. sitting height). In C (142 cm. sitting height) and D (143 cm. sitting height) he is steered to a greater sitting height by first obtaining a correct tensional balance of the head and neck. E shows calibration signals.

homœostasis in the head–neck region is usually accompanied by an overall decrease in muscular tension. Fig. 2 shows this electromyographically in six leads. The readings were made by Dr. Frank Jones.

Discussion

The rough outline which I have given may make it seem fairly easy to carry out postural re-education. It is in fact quite tricky, though extremely fascinating. The subjects had on an average 37 lessons, though usually I consider 25 to be adequate. The procedure I adopt is to give them 15 more or less consecutive daily lessons of half an hour, after which the conditioning is fairly well established. They attend once or twice a week for a two- to three-month period for reinforcement and general guidance. Optimally a six-month period should be set aside. A great deal depends on the proprioceptive intelligence of the subject.

One sees some extraordinary reactions during the process of breaking down old behaviour patterns and acquiring new ones. The physical analysis of faulty muscular patterns is almost akin to a type of psycho-analysis, in that each subject has his own habitual reactions which are unconscious and which he holds on to grimly even when they are inappropriate and harmful and in spite of his conscious wish to eliminate them. As muscular tensions are released, one may see uncontrollable reactions, such as laughter and weeping. One patient, an epileptic, came in one day saying she was on the verge of a fit. I insisted on her working in the manner indicated for 30 minutes; at the end of it she wept violently for 10 minutes, but had no fit. Next day there was a state of relaxation throughout her body which had not previously been attainable.

I have adopted this form of treatment for patients with various so-called psychosomatic disorders—those suffering from peptic ulcer, asthma, stuttering, low back pain, tension headaches, and various forms of psychoneurosis. I have also employed it in cases of displaced inter-vertebral disk, tension athetosis, and disseminated sclerosis, and in a number of cases of fibrositis, mostly of the neck and scapular region. Two conditions which respond well are spasmodic torticollis and trigeminal neuralgia ; the latter may, I think, in many cases be due to persistent head-retraction, which drags on the nerve at the foramen ovale.

It appears to me that the exercise or manipulative therapy often recommended for some of these cases which come to the physical medicine department is very wide of the mark, since it ignores the fact that the postural model, and therefore the behaviour pattern, is at fault. The patients need to be re-educated in a manner which applies to all their daily reactions. In particular, I would call attention to one great disadvantage in many exercise programmes—the difficulty of getting the patient to *want* to carry them out except under supervision. This difficulty is overcome to a large extent in a conditioning procedure. By the use of this method, insight into defective postural homœostasis is produced by what Konorski (1949) calls " latent learning ", and this is agreeable and possible for most people.

If I might indulge in a little speculation, I should like to suggest that what we now call the neurotic component of disease will eventually be more conveniently described in terms of the degree and type of interference with what I call postural homœostasis. Lashley (1949), in his paper " In Search of the Engram ", says that " the memory trace is tied in with the space co-ordinates of the animal's postural system. This system of space co-ordinates is a part of the postural reflex system which pervades every aspect of behaviour. A substratum of postural and tonic activity is constantly present and is integrated with the memory trace."

I consider that by using something like the approach I have outlined, it will eventually be possible to define the behaviour patterns more

accurately. I have been doing this sort of work for about fourteen years, and find that, although clinically it is possible to acquire a good sense of the various patterns, it is not so easy to describe and measure them. There is quite an art in eliciting the faulty behaviour patterns—in getting people to " behave badly " in front of you. Alteration in postural homœostasis is, in my experience, usually most obviously produced when the subject starts to communicate by speech or by gesture or by an activity which has a socially observable context; in other words, when he assumes a role. This seems to be related to what is called " communication psychology ". Psychoneurosis basically depends on the patient's reaction to what he thinks it necessary to communicate (or not to communicate) in some present or future situation. In the experimental approach which I employ it is possible to observe when this reaction involves interference with the postural homœostasis.

In conclusion, I should like to make a plea for physical medicine to take an interest in this sort of " constitutional " medicine. Apart from the fact that it takes in a far wider range of clinical conditions than are usually seen in the physical medicine department, our work in this specialty, as Lord Horder has recently stressed, includes " keeping people fit and making nearly fit people quite fit ". Fitness implies ability to adapt oneself to the stimuli and stresses of life. I believe that an adequate postural homœostasis is essential for that adaptation.

Summary

1. Fifty students from a London Voice and Drama College have been taught to control their postural and behavioural reactions from the head–neck region. A Konorski Type 2 conditioning procedure was employed, in the manner first described by Alexander.

2. Sheldon somatotype photographs were taken before and after re-education. Marked differences occurred in the subjects without employing physical exercises.

3. In a behavioural report on the students' progress prepared by the two professors in charge they state that this is the best form of basic training they have yet encountered.

4. The concept of " postural homœostasis " is suggested to replace fixed postural standards.

5. Various patients with psychosomatic and psychiatric disorders have been treated in this way with success. Remedial exercises or manipulative therapy are inadequate without re-education of the postural homœostasis.

6. It is suggested that in time the neurotic component of disease may more conveniently be described in terms of interference with postural homœostasis.

Acknowledgments

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A STANDARD TECHNIQUE FOR CLINICAL ELECTRODIAGNOSIS*

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ELECTRODIAGNOSIS is the name given to the study of the reaction of voluntary muscles and nerves to electrical stimuli and the analysis of the electrical activity produced by these tissues.

Until recently the classical faradic–galvanic test survived unaltered as the standard clinical test. Its continued use was remarkable; for it is essentially qualitative and gives little more information than can be obtained by clinical examination alone. Indeed, replacement of the classical method by a standard technique based on one or more of the exact quantitative methods developed for physiological research is long overdue. This paper is an attempt to reduce electrodiagnostic examination to a simple routine by the use of intensity (strength) duration or I/T curves and electromyography.

The choice of a clinical technique based on the plotting of intensity duration curves and electromyography is an obvious one. These two methods in combination have in recent years gained wide acceptance, because they can provide accurate information of great diagnostic value. It is apparent that techniques based on either one alone or on the use of progressive current ratios, galvanic tetanus ratios, strength interval curves (Arieff, 1948), or strength frequency curves (Rodriquez, Kendell, and Ivy, 1951) cannot achieve such accuracy or supply such comprehensive information.

Anatomy and Physiology

The Motor Unit

The functional unit of voluntary muscle consists of a motor nerve cell, its branching axon, and the 150 or so muscle fibres it supplies; this is called the motor unit. That many of the muscle fibres of such a unit lie adjacent and in well-defined groups within the muscle has been demonstrated histologically by Wohlfart and Swank (1941). This concept of the anatomical arrangement is also supported by the distribution of such electromyographic phenomena as fibrillation potentials and fasciculation potentials, these being generally found in compact areas within the muscle.

It is thus possible to place an electromyographic electrode at the centre of the muscle-fibre activity of a motor unit. Movement of such an electrode about this point produces a drop in amplitude of the motor-unit

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potential and, to a lesser degree, an increase in its duration. The more constant duration measurements are to be preferred as the basis for classifying muscle-action potentials.

The presence of branching of the lower motor neurones allows four anatomical divisions of the motor unit to be defined. These are the motor nerve cell, the lower motor neurone above its point of branching,

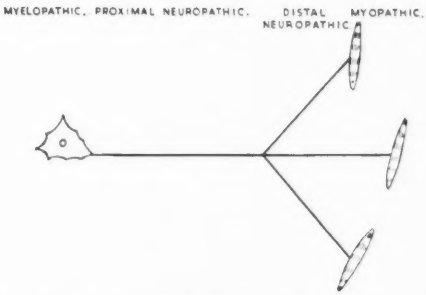

FIG. 1.—The anatomical divisions of the motor unit.

the branches of the motor neurone, and the muscle fibres. Thus, pathological lesions of this structure may be defined as myelopathic (of the cell), proximal and distal neuropathic (of the axon), and myopathic (of the muscle fibres) (Fig. 1).

The Intensity Duration Curves of Voluntary Muscles

The excitability of neuromuscular tissue may be expressed graphically by intensity duration curves. These curves are obtained by plotting the intensity of an electrical stimulus required to produce a minimal muscle contraction (along the ordinate) against the duration of that stimulus (along the abscissa).

It is well known that a stimulus applied to voluntary muscle acts in effect indirectly via the more sensitive intramuscular nerve ramifications. In complete denervation or conditions of complete neuromuscular block, however, the stimulus can act directly only on the muscle fibres. Thus, with indirect stimulation the excitability curve characteristic of motor nerves is obtained, but with direct stimulation the curve expresses the excitability of muscle fibres. It is important to realize that a block of neuromuscular transmission will give rise to the intensity duration curve characteristic of denervation, for there is growing evidence that a failure of neuromuscular transmission occurs in some forms of paralysis (e.g. polyneuritis) which are accompanied by excitability changes characteristic of denervation, but which undergo a sudden recovery incompatible with regeneration of the lower motor neurone. It is further possible that in

lesions confined to the anterior horn cell similar abnormalities in lower motor neurone or neuromuscular transmission arise. The occurrence of polyphasic motor-unit action potentials in progressive muscular atrophy and other cord lesions suggests this. The abnormal peripheral fatigue demonstrated in poliomyelitis (Hodes, 1948) also suggests an abnormality of neuromuscular transmission.

It is upon the possible coexistence of nerve and muscle tissue in the anatomical muscle, and variations of their excitabilities in nerve degeneration and regeneration, that the interpretation of intensity duration curves must be made.

The Action Potentials of Voluntary Muscles

Activity of a muscle or a nerve fibre is accompanied by changes in the cell membrane and consequently the production of an action potential. In voluntary muscles, although action potentials arise from the activity of nerve fibres, end-plates, and muscle fibres, those of the muscle fibres predominate. Therefore it is upon the analysis of these that the diagnostic criteria of electromyography are based.

Contraction of a single muscle fibre results in the production of a diphasic or triphasic action potential which has a duration of 1 millisecond and an amplitude of about 100 microvolts; this is the fibrillation potential of denervation.

Normal muscle at rest is electrically silent when examined by clinical electromyographic techniques. On voluntary contraction the smallest detectable potential is that derived from the motor unit. The almost synchronous contraction of the variable number of muscle fibres constituting this unit produces an action potential in limb muscles which is diphasic, triphasic, and polyphasic in form and has an average duration of 4–7 milliseconds and an amplitude of about 1–2 millivolts. The form of the motor-unit potential is due to slight staggering of the contraction of the muscle fibres produced by differences in the length of the branches of the lower motor neurone, possibly by differences in end-plate transmission and by differences in the distance from the recording electrodes of the muscle fibres constituting the motor unit. A further increase in the temporal dispersion of motor-unit potentials may theoretically arise from changes in any of these mechanisms—for example, in regenerating motor-unit potentials.

On maximal voluntary contraction the tetanic asynchronous discharges of motor-unit potentials summates to form the normal interference pattern. This is characterized by a low rumbling sound if demonstrated audibly, or a completely disturbed base-line if demonstrated on an oscillograph.

From a consideration of these fundamental physiological properties of muscle, electrodiagnosis based on the use of intensity duration curves

and electromyography may be conveniently divided into four procedures: (1) the plotting of intensity duration curves; (2) the study of any spontaneous action potentials in resting muscle; (3) the study of the size of the motor-unit potentials produced on minimal volition; and (4) the study of the interference pattern produced by maximal volition.

Clinical electrodiagnostic examination should be preceded by preliminary warming of the muscle. This warming increases fibrillation activity and eliminates errors due to detection of a sluggish response in cold muscle.

Nerve conduction should always be tested, as it is essential to determine the exact nerve supply of the muscle in question. Moreover, examination of nerve conduction eliminates errors arising from failure to find any motor-unit activity on volition—a state not always due to degeneration of the lower motor neurone, but which can occur in neuropraxia of the lower motor neurone and paralysis at a higher level.

The Clinical Use of Intensity Duration Curves

The apparatus used for plotting intensity duration curves generates stimuli of rectangular wave form and of specified duration. The most useful durations are 0·1, 0·3, 1, 3, 10, 30, 100, and 300 milliseconds. It is designed to produce stimuli of constant voltage (low output impedance: Ritchie, 1944) or constant current (high output impedance: Bauwens, 1941) when applied to various electrode-tissue resistances.

There is considerable controversy over the type of stimulator most suited for clinical work. The constant-voltage type stimulus is better tolerated by patients than the constant current type, but at durations of less than 300 milliseconds neither type of stimulus is painful. Although there are theoretical disadvantages in the constant-voltage type stimulus, the diagnostic efficiency of the two is comparable when they are both used correctly. However, the constant-voltage type stimulator has the disadvantage of requiring thorough skin preparation in order to lower the skin resistance. This is inconvenient when a search for a nerve trunk or motor point is made. (The use of a constant current stimulator is implied in the following descriptions of intensity duration curves.)

It is usual to plot intensity duration curves on log–linear or log–log graph paper. The latter has advantages for clinical use, as the points can then be plotted as straight lines. Further, the use of equipment with facilities for expressing intensities as multiples of the rheobase is an advantage, as it enables a rapid assessment to be made of the relative proportions of the innervated and denervated components of a diseased muscle In this way regeneration of a nerve can be followed with considerable accuracy.

Types of Curves

From Fig. 2 it may be seen that the curve obtained from normal muscle has certain characteristics by which it is readily identified. Notable is the fact that the intensity of the stimulus required to produce a minimal muscle contraction at 1 millisecond is less than twice the

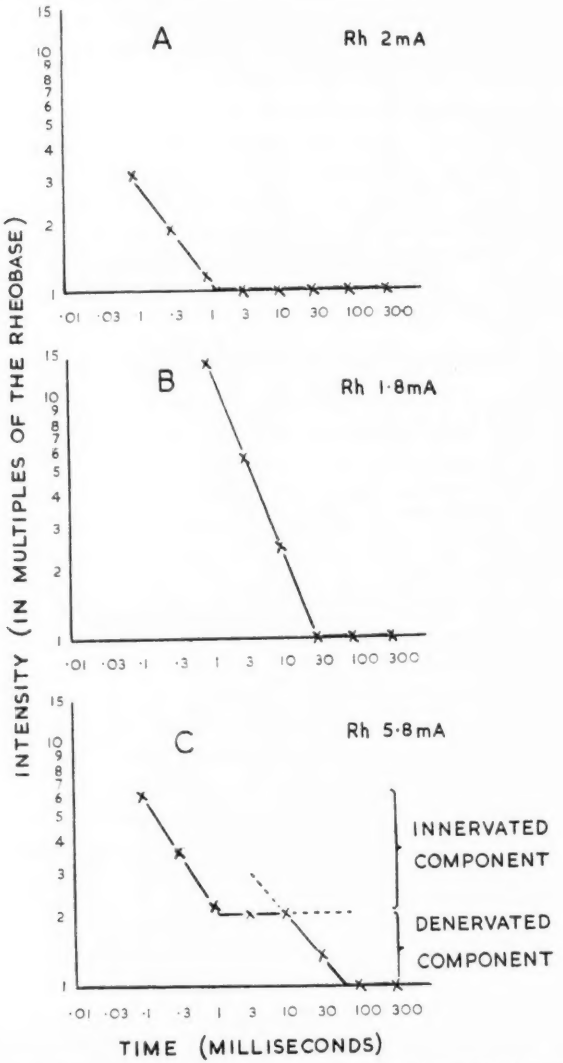

FIG. 2.—Intensity duration curves. A, Normal muscle. B, Completely denervated muscle. C, Partially denervated muscle.

rheobase—the intensity required at 300 milliseconds (Bauwens and Richardson, 1950). In denervation, however, the character of the curve changes considerably (Fig. 2). An increase in the intensity above the rheobase level is required at 10 milliseconds, and the intensity at 1 millisecond is no longer less than twice the rheobase.

The sluggish contraction of denervation is a most valuable sign. Although the exact mechanism of its production is unknown, sluggishness is observed only in four circumstances: denervation, some forms of neuromuscular block, cold muscle, and thyroid deficiency.

The intensity duration curve of partial denervation combines the features of denervated and normal curves (Fig. 2). Thus the denervated component, having a lower rheobase, produces the minimal sluggish contraction at long durations. The innervated component produces a brisk contraction at short durations (less than 1 millisecond). Since, however, some of the current is wasted in shunting through the denervated component, the threshold of the normal component is higher than that of muscle with a normal nerve supply. The fact that the rheobase of the innervated component is high may lead to a serious error in the interpretation of the intensity duration curves of partial denervation. These arise because, in the presence of oedema or resistant skin, more current than usual is required to produce muscle contraction. The output of the stimulator may not, in these circumstances, be sufficient to produce a contraction of the innervated component; the resultant incomplete curve may therefore be interpreted as indicating complete denervation.

During denervation and regeneration of the nerve, discontinuities in the intensity duration curve may appear. These seem to arise from different excitability characteristics coexisting in the muscle tissue at these stages. These variations are small and, even at these stages, intensity duration curves can be usually resolved into one (normal or denervated curves) or two (partially denervated curve) components.

Clinical Use of Electromyography

By the use of suitable electronic apparatus the electrical activity of voluntary muscles can be studied. Many systems of detection, amplification, and recording of muscle-action potentials have been described; but for clinical work standard equipment is now available consisting of concentric needle electrodes (standard wire gauge 24), single-channel amplifier with cathode-ray tube, loud-speaker, and voltmeter (average reading).

It has been shown that the potentials derived from muscles by conventional single-core needle electrodes (concentric or coaxial) are comparable with those derived from monopolar needle electrodes (Landau, 1951). However, since concentric needle electrodes are more durable and less damaging to tissues than monopolar needle electrodes they are to be recommended for use in clinical electromyography.

The importance of the amplifier has recently been emphasized by Buller and Styles (1952). In general it may be said that a differential amplifier with a response of from 6 decibels down at 10 cycles to 6 decibels down at 5 kilocycles should be used.

The use of a complicated recording method for clinical work is unnecessary, because clinical electromyography consists essentially in sampling pathological muscle with a needle electrode and identifying the type of potentials encountered at rest and on volition. As will be shown below, the possible types of potential that are of diagnostic significance fall into definite groups and are distinctive.

Errors can arise from failure to recognize electrical interference detected by an electromyograph. In Fig. 3 four types of interference

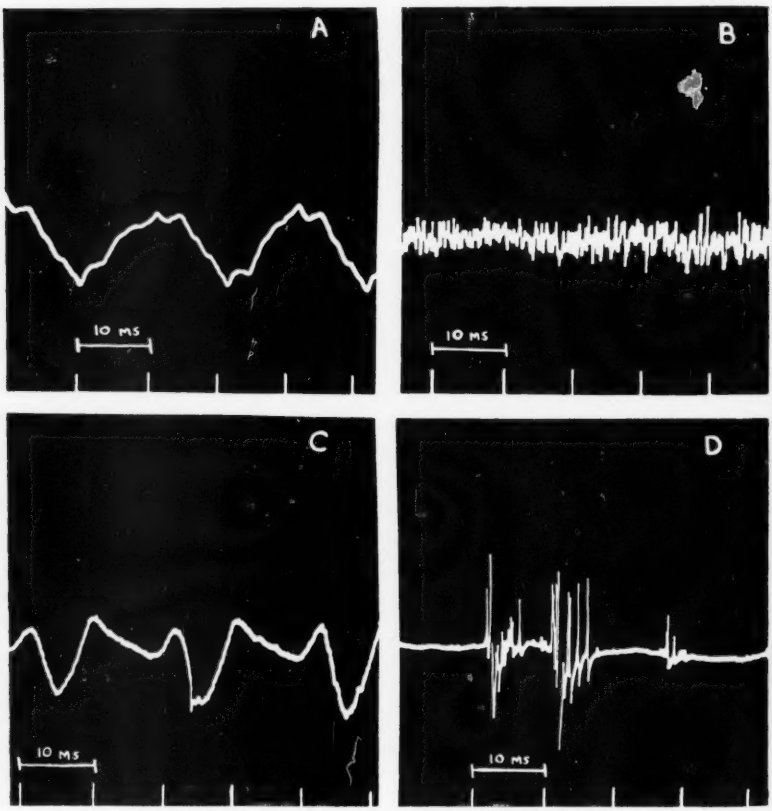

FIG. 3.—Electrical interference detected by electromyography. A, 50-cycle "hum". B, Valve noise. C, Diathermy. D, Loose contacts.

commonly encountered are illustrated. They are 50-cycle "hum", diathermy, valve noise, and loose or broken contacts.

Types of Muscle Action Potentials

1. SPONTANEOUS ACTIVITY IN VOLUNTARY MUSCLES.—In pathological conditions four types of spontaneous activity may be detected in muscles: fibrillation potentials (Fig. 4 A), fasciculation potentials (Fig. 4 B), grouped motor-unit discharges (Fig. 4 C), and high-frequency discharges (Fig. 4 D).

(*a*) *Fibrillation Potentials.*—These spontaneous single muscle-fibre potentials are most easily recognized by the regular clicking sound (2–20 per second) they produce They occur in denervation, and are due to the contraction of individual fibres in response to chemical or

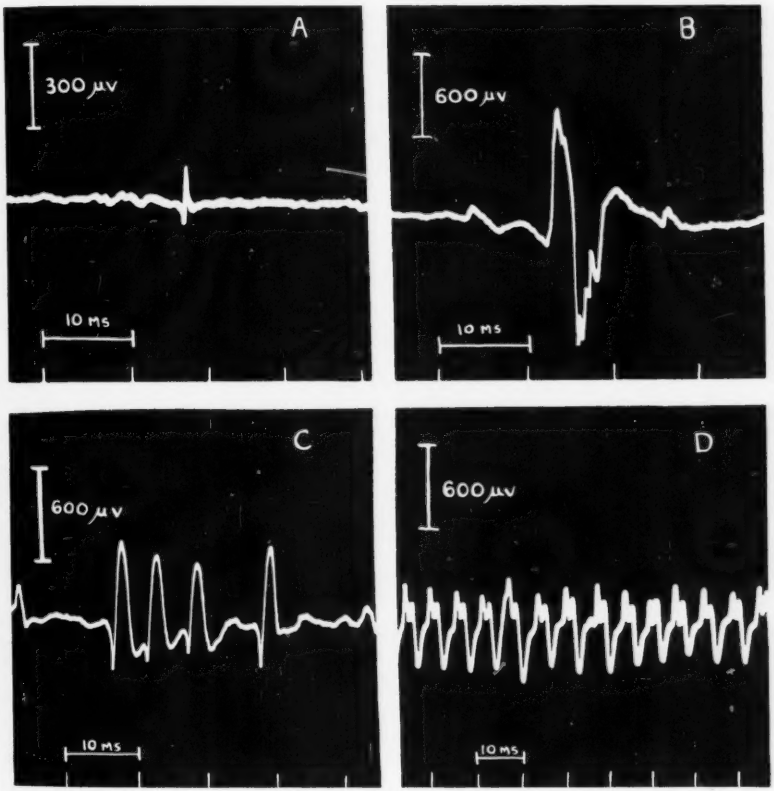

FIG. 4.—Types of spontaneous muscle-action potentials. A, Fibrillation potentials. B, Fasciculation potentials. C, Grouped motor-unit discharges. D, High-frequency discharges.

mechanical stimuli. They are increased by heat and neostigmine. Fibrillation also occurs in showers during insertion of a needle electrode.

The difference between spontaneous activity and needle-insertion activity is arbitrary. However, the momentary shower of activity which accompanies needle movement in the tissue, and which is difficult to interpret, is easily distinguished. Consequently errors may be avoided if the needle is allowed to rest before analysis of potentials is undertaken. Fibrillation potentials are not constant in denervation (Richardson, 1951a), and it is for this reason that intensity duration curves must be used with electromyography if accurate electrodiagnosis is to be achieved.

(*b*) *Fasciculation Potentials.*—These spontaneous motor-unit potentials are again most easily recognized by sound. They are sometimes referred to as slow sporadic fasciculation potentials (Hirschberg and Abramson, 1950). They are often of large size, polyphasic, and occur irregularly at about 1–10 per minute. Fasciculation occurs in progressive lesions of the anterior horn cells such as motor neurone disease (amyotrophic lateral sclerosis and progressive muscular atrophy), peroneal muscular atrophy, intramedullary tumours, and syringomyelia.

It has been shown that fasciculations continue after section of the motor nerve (Forster, Borkowski, and Alpers, 1944), and it therefore appears that their origin must be in the peripheral portion of the nerve fibre or in the myoneural junction. The almost synchronous contraction of all the muscle fibres of a motor unit which must occur to give fasciculation the form of motor-unit potentials can be explained by an axon reflex such as has been demonstrated by Masland and Wigton (1940).

Isolated motor-unit potentials occurring at an irregular frequency may also be found in the nerve-compression syndromes (see below).

(*c*) *Grouped Motor-unit Discharges.*—This electromyographic phenomenon consists of the regular activity of grouped repetitive discharges of a motor unit. Their sound and appearance are very characteristic. They occur with single motor-unit potentials in cases of nerve irritation from pressure—e.g. prolapsed intervertebral disk, cervical rib, carpal tunnel syndrome, and facial contracture. They also appear in tetany, uraemia, and the benign fasciculations of myokymia (Denny-Brown and Foley, 1948). The exact mechanism of their production is not fully understood, but it is apparent that they are due to spontaneous nervous impulses arising in the lower motor neurone, in some cases in an area of ischaemia (Kugelberg, 1946).

The detection of spontaneous motor-unit activity and other signs of nerve damage may be used for the location of nerve-root lesions. These findings are, however, not constant even in the presence of neurological signs of nerve pressure. Myokymia may also give rise to grouped potentials consisting of many more discharges. Very occasionally progressive muscular atrophy, polyneuritis, poliomyelitis, and fatigued

muscle may produce these large groupings. They are similar to high-frequency discharges in having a frequency of about 10 per second, and it is therefore debatable whether they should be classified under grouped discharges or under high-frequency discharges. They are sometimes referred to as fast rhythmic fasciculation.

(*d*) *High-frequency Discharges.*—These consist of protracted trains of oscillations which occur in a variety of forms. Some have dimensions comparable with single-fibre potentials, others resemble motor-unit potentials, and some are bizarre in form. They are remarkable for their change in pitch, which makes them sound like a diving aeroplane. Their frequency may be 100–150 per second, dropping down to 10–20 per second (Buchthal and Clemmesen, 1941a), and the dramatic quality of the sound caused by this phenomenon has led to the appellations " dive-bomber " and " quasi-musical ". They occur in myotonia congenita (Thomsen's disease) and dystrophia myotonica, which also exhibit a fibrillary after-discharge following voluntary contraction. They may be found during muscle-cramps.

Apart from spontaneous activity produced by lesions of the motor unit, rhythmic patterns of motor-unit activity may be found in the involuntary movements characteristic of some diseases of the central nervous system. Although these tremors are difficult to differentiate by electromyography, the alternate bursts of interference pattern in opposing muscles in Parkinson's disease are characteristic (Clare and Bishop, 1949).

Muscular twitches of apparent spontaneity may occur in cross-reinnervation—for example, following brachial-plexus lesions, motor-unit potentials with a respiratory rhythm may be detected in biceps and brachioradialis muscles.

2. Size of Motor-unit Potentials on Minimal Volition.—Minimal voluntary contraction of normal muscle is accompanied by the activity of a few motor units only. At this stage the dimensions of the potentials produced by these units may be studied easily. Progressive increase in the strength of contraction brings into play other units which, in normal muscle, tend to have larger potentials than those initiating contraction. In fatigue it is the large potentials that survive the small ones.

Four types of motor-unit potentials may be differentiated: those of normal dimensions (Fig. 5 A), highly polyphasic long-duration potentials (Fig. 5 B), large motor-unit potentials (Fig. 5 C), and small " broken-up " motor-unit potentials (Fig. 5 D).

(*a*) *Normal Motor-unit Potentials.*—The size of motor-unit potentials in normal muscle has been defined by Weddell, Feinstein, and Pattle (1944), who state that the average duration is 5–10 milliseconds. More recently, in summarizing the results obtained by various investigators, Petersen and Kugelberg (1949) gave an average duration of 7 milliseconds

for motor-unit potentials obtained from the interossei and biceps muscles. In facial muscles an average of 2 milliseconds was obtained.

(*b*) *Highly Polyphasic Long-duration Potentials.*—These long-duration motor-unit potentials occur characteristically in reinnervation. They are of low amplitude (up to 500 microvolts) and long duration (about 15 milliseconds). The appearance of increasing numbers of motor-unit

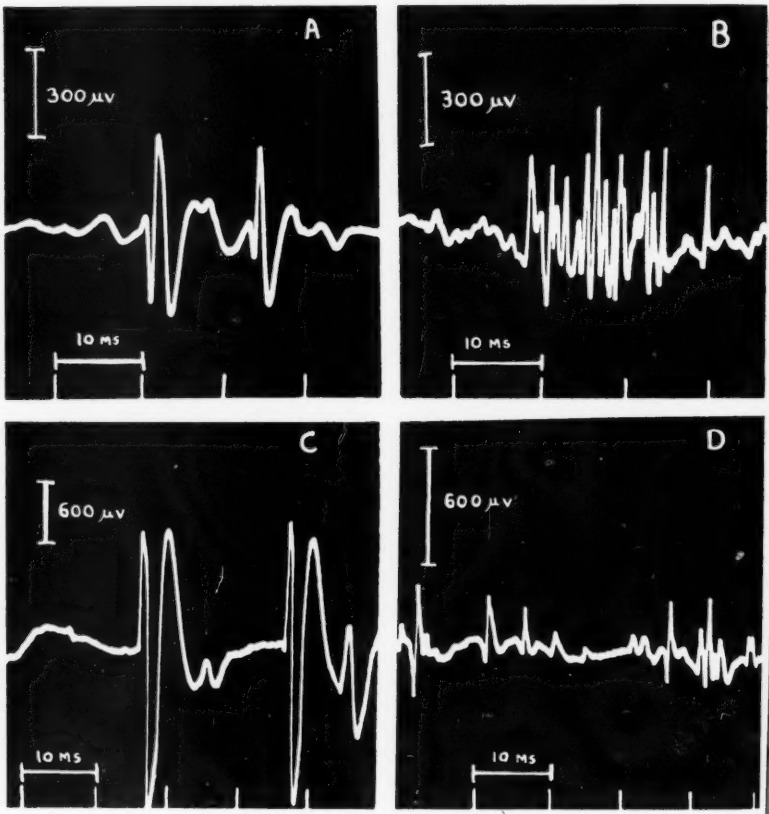

FIG. 5.—Motor-unit potentials initiating voluntary contraction. A, Normal motor-unit potentials. B, Highly polyphasic long duration potentials. C, Large motor-unit potentials. D, "Broken-up" motor-unit potentials.

potentials becoming more and more polyphasic, and the difficulty of detecting fibrillation potentials, are characteristic of reinnervation. Polyphasic potentials alone can also be detected during degeneration of the lower motor neurone.

Although in degenerative conditions the highly polyphasic potentials generally have higher amplitude than those found in reinnervation, the differentiation can be extremely difficult. The temporal dispersion of regenerating motor-unit potentials appears to be largely due to the retarded conduction rate in the regenerating lower motor neurone.

(*c*) *Large Motor-unit Potentials.*—The presence of motor-unit potentials of large amplitude and greater duration than normal has been noted by several workers (see Kugelberg, 1949) in some cases of neurogenic atrophy. This change and the finding of increased numbers of polyphasic motor-unit potentials are particularly marked in myelopathic lesions and may be used in their diagnosis. The phenomenon of synchronization of motor-unit activity (Buchthal and Clemmesen, 1943) is undoubtedly related to the presence of these large units.

Denny-Brown (1944), on comparing the mechanical and the electrical response of motor-unit activity, deduced that the phenomenon of synchronization was due to the detection by two or more needle electrodes of the same, often large, motor-unit potential. He related the ease with which this single large motor-unit potential could be detected to the uncovering of its activity by loss of the smaller motor-unit potentials. These normally summate with the large unit potentials to form an interference pattern. Richardson (1951b) has produced evidence to show that two potential sources, which can sometimes be demonstrated in synchronization, can be explained by the presence of branched motor units.

(*d*) *Small "Broken-up" Motor-unit Potentials.*—A predominance of motor-unit action potentials of short duration and increased polyphasicity, sometimes referred to as disintegration of motor-unit potentials, is characteristic of myopathic lesions (Kugelberg, 1949). This change occurs in the muscular dystrophies, dystrophia myotonica, dermatomyositis, and myasthenia gravis on fatigue. It also occurs in distal neuropathic lesions—that is, in lesions below the point of branching of the lower motor neurone (e.g. polyneuritis). These potentials, which are produced by loss of muscle-fibre activity within the motor unit, are found only in advanced lesions; consequently myopathic lesions are diagnosed most often by the failure to obtain signs of denervation, rather than by the detection of broken-up motor-unit potentials.

It is this, the second stage of electromyographic examination, that is the most difficult. Considerable skill is required to recognize over-all changes in the type of motor-unit potentials initiating volition. Because of this difficulty, such electronic aids as magnetic tape recording (Bauwens, 1950), and methods based on the analysis of the frequency components of motor-unit potentials (Richardson, 1951b; Walton and Osselton, 1952), have been introduced. The latter method is based on the principle that an increase in the higher-frequency components of motor-unit potentials

occurs in the presence of " broken-up " motor-unit potentials and highly polyphasic potentials.

3. The Interference Pattern Produced by Maximal Volition.—Summation of the motor-unit potentials detected by a needle electrode on maximal volition is a criterion of normality. Lesions producing inactivity of the whole motor unit—that is, lesions situated above the point of branching of the lower motor neurone (myelopathic and proximal neuropathic)—result in a failure to obtain this interference pattern. Lesions below this point (distal neuropathic and myopathic) result in

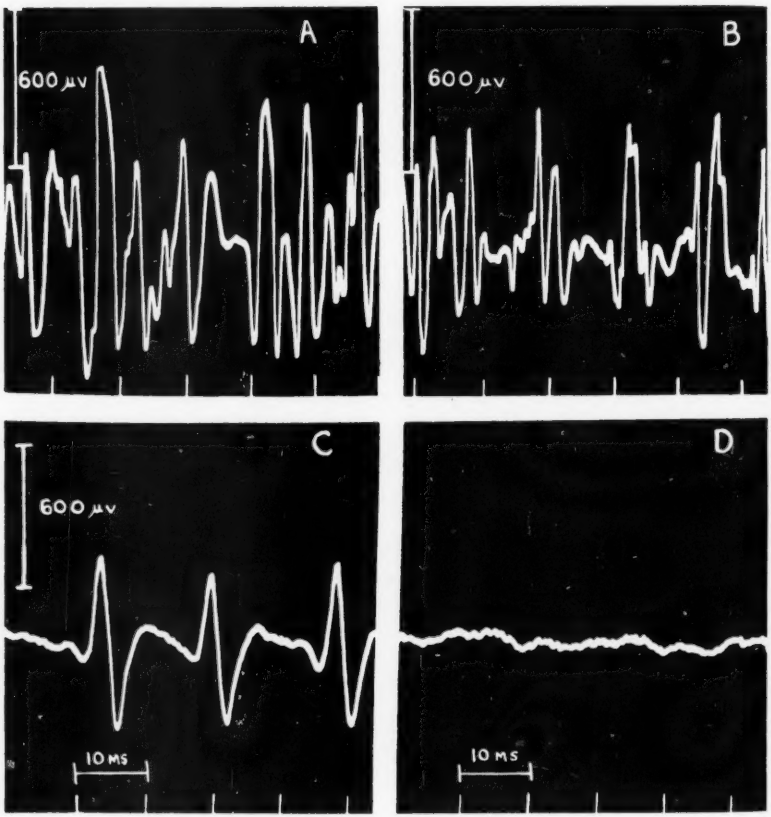

Fig. 6.—Types of interference pattern. A, Normal. B, Reduced. C, Discrete. D, No motor-unit activity.

changes in the individual motor-unit potentials, but enough motor units are preserved for their potentials to summate into an interference pattern.

Findings at this stage of an electromyographic examination are classified into four according to the increasing severity of the lesion: normal interference pattern (Fig. 6 A), reduced interference pattern (Fig. 6 B), discrete or single motor-unit activity (Fig. 6 C), and no motor-unit activity (Fig. 6 D).

The absence of motor-unit potentials on attempted volition is a finding of some importance in peripheral-nerve injuries. In the absence of nerve conduction and the presence of intensity duration curves characteristic of complete denervation, it indicates a complete lesion of the nerve.

Location of Motor-unit Lesions

The electrodiagnostic findings described above may be used as follows to locate the part of the motor neurone which is affected.

1. *Myelopathic Lesions.*—(*a*) Signs of denervation (intensity duration curves showing partial or complete denervation; electromyogram showing fibrillation potentials) are present. (*b*) Spontaneous fasciculation potentials may be present. (*c*) Initiation of voluntary contraction gives large and often polyphasic motor-unit potentials. (*d*) A full interference pattern is not obtained on maximal volition.

2. *Proximal Neuropathic Lesions.*—(*a*) Signs of denervation are present. (*b*) Irritative lesions may give grouped discharges. (*c*) Initiation of voluntary contraction gives motor-unit potentials of normal size. (*d*) During degeneration and regeneration highly polyphasic, long-duration potentials appear.

3. *Distal Neuropathic Lesions.*—Signs of denervation are combined with those of a myopathic lesion—i.e. small "broken-up" motor-unit potentials initiating voluntary contraction which summate on maximum volition to form a full interference pattern. Distal and proximal neuropathic lesions can occur together—e.g. polyneuritis.

4. *Myopathic Lesions.*—(*a*) Signs of denervation are absent. (*b*) Individual motor-unit potentials are of short duration and "broken up". (*c*) Full interference pattern is obtained on maximal volition. (*d*) High-frequency discharges are found in profusion in the myotonias.

Summary

1. The replacement of the classical galvanic–faradic test by a more comprehensive method of electrodiagnosis is desirable.

2. A suitable method exists in the combined use of intensity duration curves and electromyography.

3. A clinical technique based on this combination consists of: (*a*) the correct interpretation of the intensity duration curves characteristic of normal, completely denervated, and partially denervated muscles; (*b*) the identification of spontaneous muscle-action potentials—i.e.

fibrillation potentials, fasciculation potentials, grouped motor-unit discharges, and high-frequency discharges—and the recognition of their association with various lesions; (*c*) the identification of the motor-unit potentials initiating muscle contraction—i.e. normal motor-unit action potentials, highly polyphasic long-duration potentials, large motor-unit potentials, and "broken-up" motor-unit potentials; and (*d*) the estimation of the degree of interference produced by the motor-unit potentials on maximal volition.

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NOTE.—The illustrations of muscle-action potentials are taken from magnetic tape recordings displayed on a cathode-ray tube.

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RECENT ADVANCES IN SHORT-WAVE DIATHERMY*

By B. O. SCOTT

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SINCE D'Arsonval first studied the effects of high-frequency currents on the human body and Tesla observed their heating action, short-wave diathermy has been used extensively in medical treatment. Short-wave diathermy is the heating of living tissues by high-frequency currents oscillating at between 10 and 100 megacycles per second. As the word "diathermy" implies, it heats the tissues of the body throughout. Heat-production depends only on the to-and-fro movement of the ions in these tissues when they are placed in the short-wave field (Boyle, Cook, and Buchanan, 1950). The application of this form of energy to medicine has a firm foundation in laboratory and clinical trials, in contrast to many physiotherapeutic procedures, which, at most, are empirical, and often without scientific basis.

Heating by Short-wave Diathermy

The heat generated within any material by a high-frequency current is related to the field strength, and also to the power factor and dielectric constant of the material. It is evenly distributed if the field is uniform and the material homogeneous. In practice, the former is controlled by the size, shape, and positioning of the electrodes. The tissues of the human body are not homogeneous, however, and therefore heating is not uniform. Fat will take up more heat in a condenser field than vascular tissues, because of its low dielectric constant and high power factor. Muscle is best heated by inductothermy, for the eddy currents produced by electromagnetic induction flow more easily in tissues with the highest conductivity—that is, those with the greatest water content.

Whilst it is clear that short-wave diathermy, although not evenly distributed through the tissues, is a satisfactory method of heating the human body, there are two main disadvantages with the apparatus and technique now available. (1) Dosage is empirical, for there is no way of measuring the energy dissipated in the tissues; the only method of estimating the applied current depends on the sensitivity of the individual patient (Kobak and Mittelman, 1940). (2) When a short-wave circuit becomes detuned there is a gross falling-off in power transmission to and

* Paper read at the Annual Meeting of the British Association of Physical Medicine on April 26, 1952.

from that circuit. This detuning is occurring continually in short-wave therapy owing to alterations in the circuit constants resulting from movements of the patient and operators.

If the power input into the patient could be measured, and the circuit continually re-tuned in response to alterations in the circuit constants, this loss of power could be avoided and accurate dosage achieved. With these objects in mind, a self-tuning short-wave machine with wattmeter was conceived by Bauwens, designed by Styles, and produced in the Electronics Department of St. Thomas's Hospital.

The Self-tuning Short-wave Apparatus

The apparatus (Plate I) contains a master oscillator incorporating a quartz crystal with a natural frequency of 6·78 megacycles per second (mc./sec.). The output from this oscillator is taken to a harmonic amplifier which selects the second harmonic of this frequency. The output of this amplifier is therefore at a frequency of 13·56 mc./sec. This output is then passed to a second harmonic amplifier and thus the frequency is again doubled to 27·12 mc./sec. This latter oscillatory current with a frequency of 27·12 mc./sec., together with the output of another 100 kc./sec. oscillator, is fed to the grids of a conventional "push–pull" pentode amplifier. This arrangement produces two side-bands in addition to a carrier wave. There are therefore, at this stage in the circuit, three frequencies: the carrier wave 27·12 mc./sec. and the two side-bands 27·02 mc./sec. and 27·22 mc./sec. The relative amplitudes of these side-bands are used to control the tuning unit (*vide infra*). The three step-ups of the frequency of the carrier wave—from 6·78 mc./sec. to 27·12 mc./sec.—are necessary because a quartz crystal thin enough to have a natural frequency of 27·12 mc./sec., which is the desired output frequency, would be extremely fragile. The master oscillator is arranged to operate at 6·78 mc./sec., so that a strong crystal of this resonant frequency can be used. The power output is increased at the same time in the harmonic amplifiers. The power output of the final amplifier is taken from the machine to the tuning unit and the patient's circuit by a link made up of co-axial cable.

Incorporated in this co-axial cable link are two bridges: one measuring the total output of the machine and the other indicating the presence or absence of standing waves on this co-axial line. A loss meter—which has also been incorporated—will not record accurately in the presence of standing waves. (Plate II B.)

The patient's circuit is essentially the same as in the conventional ultra-short-wave diathermy apparatus. The alteration of the capacity of the tuning condenser (that is, tuning of the patient's circuit) is controlled

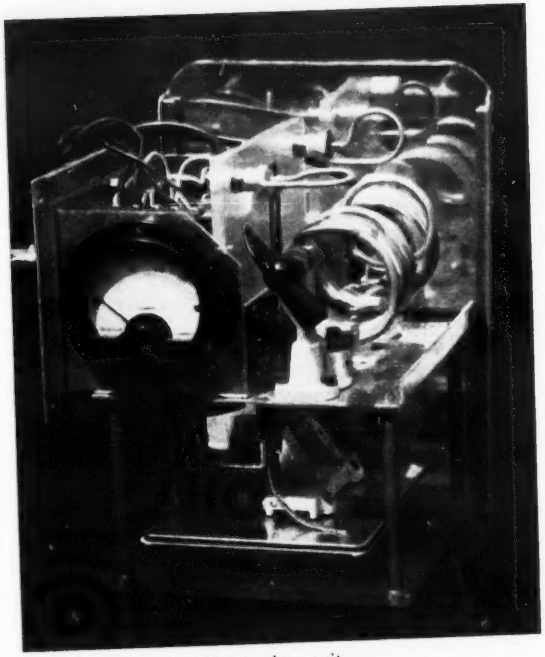
PLATE I.

Left: The self-tuning short-wave diathermy apparatus fitted with a wattmeter.

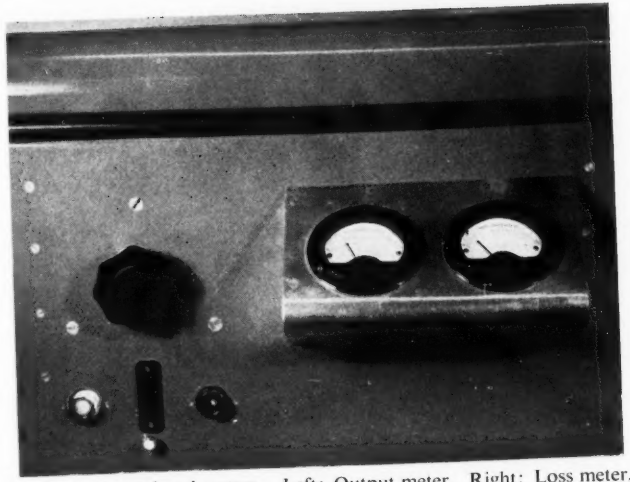
Right: Back of the machine.

[face p. 104.

PLATE II.



A. The tuning unit.



B. Control panel and meters. Left: Output meter. Right: Loss meter.

by means of a reversible electric motor. From the inductance coil in the patient's circuit a second link coil picks up current by induction and takes it to the loss meter; this is calibrated to read in watts the losses which occur in this coil. Local tissue absorption of power cannot be measured direct because the energy introduced into the tissues is immediately transformed to heat; this will not be distributed uniformly, and some will be conveyed by the blood to other parts of the body. It is possible only to measure the power output from the condenser formed by the electrodes, cables, and patient. The actual power input into the patient, therefore, is the reading of the machine-output meter less the reading of the loss meter.

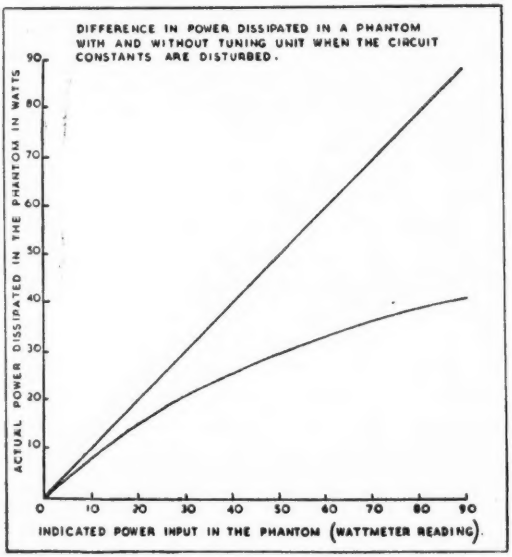
A third link picks up currents which are passed down a co-axial line to the tuning unit. The currents are passed through two "band-pass filters", one of which passes 27·02 mc./sec. only, and the other 27·22 mc./sec. These two currents, after rectification and amplification, are applied to the split field windings of the electric motor in such a way that if the resonant frequency of the patient's circuit alters, for example, from 27·12 mc./sec. towards 27·22 mc./sec. the amplitude of the 27·22 mc./sec. side-band is increased and that of the 27·02 mc./sec. side-band decreased. The unequal currents in the field of this motor cause it to rotate, and this alters the capacitance in the output circuit until it regains its resonant frequency of 27·12 mc./sec.

Thus, whenever the capacitance in the patient's circuit is altered by movements of patient or operators, resulting in detuning of the circuit, the motor varies the condenser in the tuning unit, bringing it back into resonance; the gross variations of power output which normally occur when the patient's circuit is detuned are therefore avoided.

Experiments Performed to Test the Value of the Tuning Unit

The apparatus was set up with constant spacing of the electrodes about a standard phantom. The losses were kept constant. The machine was then allowed to put power into the phantom for a given time with the tuning unit in operation. Throughout these experiments the output frequency was tested with frequency meters and the field estimated with neon bulbs. These operations necessitated the approach of capacitative bodies within the field of radiation of the electrodes and cables. In fact, a state of affairs was produced identical with that taking place during clinical treatment. The amount of power passing into the load was calculated. This experiment was repeated with the tuning unit out of action. Graph 1 shows that the input into the phantom load with the tuning unit in operation is considerably greater than the input into the load without self-tuning.

The next condition of operation investigated was continual variation of the load itself—for example, in treatment of the thorax or abdomen. In this experiment the load was represented by two rubber bags joined together by a wide-bore tube, one bag being placed outside the active field of radiation. The apparatus was set up as before, and during its operation water was transferred to the bag under treatment, and withdrawn again, by raising and lowering this bag (outside the active field of radiation) at a constant rate. The number of watts put into a known



GRAPH 1.

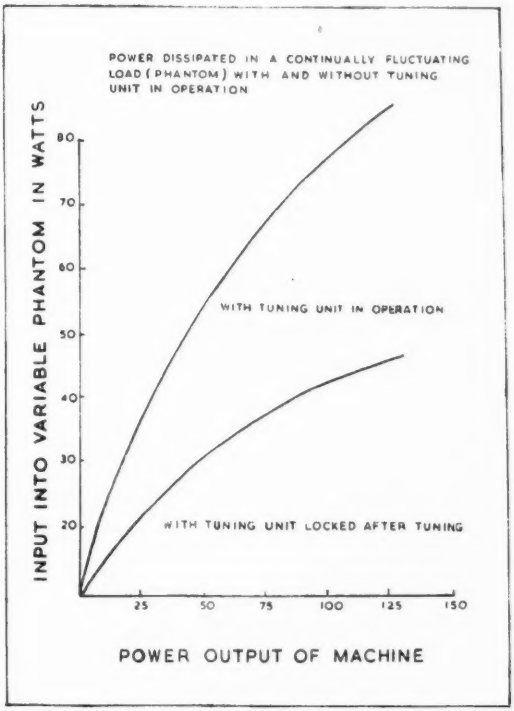
quantity of water in the system was calculated. The experiment was repeated with the tuning unit out of action. It was observed that the input into the load was again considerably greater with the tuning unit in operation. The output of the machine was varied during these experiments. The results are shown in Graph 2.

The self-tuning mechanism adjusts itself with accuracy to the changes produced by thoracic or abdominal movements. When the upper limb is being treated the unit will respond to movement of the head or other arm if this should be sufficient to cause a detuning of the circuit. The same conditions apply in the treatment of the lower limb. From these

experiments it may be concluded that the sensitivity of the unit is satisfactory.

Experiments to Establish the Accuracy of the Wattmeter

The wattmeter was calibrated in the laboratory. To determine whether or not it was accurate, phantoms containing tap water were used and experiments carried out to test the efficiency of the meter with all possible variations in the load. These were produced by using phantoms of

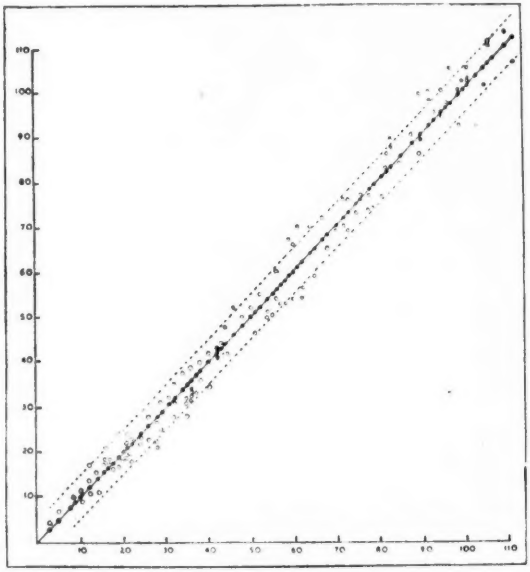


GRAPH 2.

different shapes and sizes; by altering the spacing between the load and the electrodes; by using different sizes of electrodes; and by placing the electrodes in different positions.

The output of the apparatus was varied in all experiments. For example, a reading was taken with longitudinal positioning, large electrodes, 1¼-inch spacing, and with an output first of 50 watts, then of

100 watts, and then of 150 watts. The spacing was then changed to $1\frac{1}{2}$ inches and the readings repeated. Further variations in spacing and output, etc., were made until a large range had been covered. Various-sized electrodes were then employed; 425 readings were taken, and averages of the results are plotted on Graph 3, which shows the actual watts absorbed by the phantom against the watts measured by the wattmeter. The straight thick line represents the estimated power in



GRAPH 3.

watts and the dots represent actual power; this was calculated from the formula—

$$\text{Power} = \frac{(\text{temperature rise} \times \text{S} \times \text{volume of water}) \times \text{J}}{\text{time}}$$

where S=specific heat, J=Joule's equivalent, and time=the time for which the current flowed. The two dotted lines on either side of the thick line indicate an error range of 5 watts. It will be seen that the majority of the readings lie within an error of + or −5 watts of the estimated input into the load. It can therefore be deduced that the wattmeter is accurate, but it must be remembered that, while the meter records the total input into the load, it cannot give any information as to the exact local dissipation of energy in the various components of that load.

Recent Advances in Short-wave Diathermy

Summary

1. There are two main drawbacks to the efficient use of short-wave diathermy: power loss due to detuning of the patient's circuit, and empirical dosage.

2. To overcome these drawbacks a self-tuning short-wave generator with wattmeter has been designed.

3. Power losses from detuning are avoided by placing in the patient's circuit a condenser which automatically adjusts itself to changes in the total capacitance.

4. The wattmeter measures the power input into the patient.

5. Whether a wattmeter will be as great an advantage in short-wave therapy as was hoped is open to question, but it has been shown experimentally that the tuning unit operates effectively and accurately.

Acknowledgments

I wish to thank Dr. Bauwens for his valuable and helpful advice at all times. This work was made possible by a grant from the Nuffield Foundation Trust.

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ABSTRACTS OF WORLD LITERATURE

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Practical Treatment of Uncomplicated Fractures of the Vertebrae. C. M. BURGES and V. C. WAITE. *Amer. J. Surg.*, June, 1951, lxxxi, 689.

Plaster of Paris and metal were unobtainable on Sumatra during the war, and Dr. Conrad Bornhaupt, who was interned by the Germans, relied on muscle tone alone in the treatment of uncomplicated fractures of the spine. First, the fracture is reduced by a short period of hyperextension accomplished by placing a tightly-wound blanket roll transversely across a thin firm mattress on boards. By varying the thickness and position of the blanket roll, any compression fracture can be rapidly and adequately reduced with minimum discomfort. Depending on the patient's response, the reduction is maintained for a few days or a week. He is then turned to the prone position and systematic hyperextension exercises are begun. The hands are placed at the sides of the patient and he is told to dorsiflex his neck in an attempt to raise the sternum off the mattress. When this has been mastered he is asked to raise his knees off the bed by using the lumbar and posterior thigh muscles, keeping the knees fully extended. Finally, the two exercises are performed simultaneously. At first this is difficult, but within a few days the patient is able to hyperextend the entire spine with only the abdomen remaining in contact with the mattress. These exercises are carried out as often as the strength of the patient permits, but at least ten times every few hours. After the exercises, the patient can be turned on his back, but great care should be taken to avoid recurrence of the compression. Hyperextension is maintained with the blanket roll. In a week or two the spinal muscles become so hypertrophied that they are able to maintain adequate hyperextension of the spine.

In repeating this work, the authors at first used Taylor braces to prevent unconscious flexion of the spine, but soon found this unnecessary. Of 25 patients treated thus far (5 in their late sixties) only 2 had residual pain; 7 were compensation cases. All returned to work within 6 months without permanent disability (follow-up period was 9 to 54 months).

On the Treatment of Dupuytren's Contracture. LENNART SODERBERG. *Acta orthopaed. scand.*, 1951, xx, 184.

In the opinion of the author, radical surgery is the procedure of choice in Dupuytren's contracture in young patients. Two weeks after operation patients are allowed to use their hands and are instructed in finger-joint exercises usually performed twice daily in a warm hand bath. Excellent results are reported in 55 per cent. of the cases and fair results in 38 per cent.

Abstracts

Mesures des Infrarouges en Clinique. JEAN DUMOULIN. *Acta physiother. rheum. belg.*, December, 1950, v, 333.

The author has designed an infradosimeter which permits the measurement of the number of calories of heat which reach the skin from luminous heat sources in calories per square centimetre per minute. The instrument consists of a disk of copper to absorb the heat rays and pass them on to a thermocouple, and a small shield of wood between the thermocouple and the skin to prevent the effects of reflected radiation. The device is placed very close to, but not touching, the skin. With this device the author has found that the heat developed in the skin is proportional to the incident energy at the beginning of treatment. The treatment temperature depends upon the circulation, the nerve innervation, the climate of the treatment room, and the involvement of the skin by disease. He also found that highest skin temperatures are reached when the part to be treated is placed in a plane perpendicular to the light source.

Vocational Guidance in Denmark. Social Tidsskr., November, 1950.

Plans have been developed for a comprehensive vocational guidance service in Denmark, financed by State funds. The service will be closely integrated with the existing employment service and with the guidance service for all who complete public schooling. Until enough workers become available, emphasis will be placed on group discussions and lectures on vocational opportunities and problems. (At present there are only thirteen vocational counsellors in Denmark.) The service will first be introduced in cities and towns and will be brought before Parliament during this year.

Der Phantomschmerz und seine Behandlung mit Ultraschall. D. SCHAREK. *Arch. phys. Ther.*, 1951, iv, 233.

Phantom pain in amputation stumps was relieved by ultrasound to the stump and appropriate nerve roots with a 2-watt intensity for 5 to 10 minutes. Relief was obtained in all of 8 patients treated, and the author attributes the response to a direct action on the sympathetic nerves.

Die Spezificitat der Biologischen und Therapeutischen Ultraschallwirkung. J. LEHMANN. *Arch. phys. Ther.*, 1951, ii, 57.

On the basis of experiment the author believes that the effective factor in ultrasound therapy is heat, although the other energy elements are conceded a minor role. Under the influence of ultrasound an increased chlorine ion exchange through animal tissues could be observed which cannot be explained on the basis of heat alone.

The Necessity of Teaching Physical Medicine in Polish Medical Schools. Z. OSZAST. *Polski Tyg. lek.*, February, March, 1950, v, 357, 393, 440, 515.

In arguing for medical school acceptance of physical medicine instruction the author states that the subject is taught in medical schools of other countries and that 15 schools in the U.S.S.R. give regular courses in physical medicine. Dr. Oszast discusses the history of physical medicine at great length and evaluates different modalities in detail. He asks for a 20-hour integrated course followed by a final examination, and asks that postgraduate facilities in

physical medicine be offered in Poland. At present there are three physical medicine departments in Krakow, staffed by five physicians and 30 technicians. These take care of 600 patients a day. The author gives a long list of references, none after 1942. He fails to mention rehabilitation.

The Treatment of Rheumatoid Arthritis. J. GOSLINGS. *Ned. Tijdschr. Geneesk.*, July 29th, 1950, xciv, 2162.

This item was written for the general practitioner and is of interest to readers because it shows the difficulties encountered elsewhere in the treatment of rheumatoid arthritis. Most striking is the still uncommon practice of putting the acute arthritic in hospital in the Netherlands. A strong plea is made for early hospitalization and treatment. Routine physical therapy procedures are described as important. The author considers infra-red as the ideal form of heat; the use of moist heat is not mentioned. According to the author, continued ambulatory treatment may lead to early ankylosis. There is no mention of obtaining ankylosis in functional positions in those patients where ankylosis cannot be prevented.

Chronic Absorptive Arthritis or Opera-glass Hand. WALTER M. SOLOMON and ROBERT M. STECHER. *Ann. rheum. Dis.*, September, 1950, ix, 209.

The authors' summary best reviews this interesting and well-illustrated article. "The clinical features of eight patients with chronic absorptive arthritis, sometimes called 'mains' or 'doigts en lorgnette', include generalized long-standing severe rheumatoid arthritis with the additional extraordinary findings of shortening of the fingers or wrists with increased range and direction of motion, redundancy of the skin, and extensive absorption of the bones of the affected joints—an extreme manifestation of rheumatoid arthritis."

Further Experiences with Hypophyseal Implantation in Rheumatoid Arthritis. GUNNAR EDSTRÖM and STIG THUNE. *Svenska Läkartidn.*, February, 1951, xlviii, 456.

The hypophyses of calves or pigs were implanted in the gluteals of 100 patients with rheumatoid arthritis. After nine months 50 per cent. were much improved, 25 per cent. improved but suffered relapse, 25 per cent. showed no improvement. The response resembled that seen after ACTH therapy. The authors plan to continue this project and mention that a motion picture film of the procedure is available for distribution.

Prova Termometrica associata nello Studio delle Arteriopatie Obliteranti. E. MALAN and G. ENRIA. *Minn. med.*, June 9th, 1950, xli, 213.

In spite of all precautions, skin thermometry by itself is not of great value in studying peripheral vascular disease. A difference of 2 C.° between symmetrical areas is suggestive of vascular disturbance but does not confirm it. On the other hand, when used in conjunction with functional tests, skin thermometry is very useful. Among the functional tests is that of Brown, in which the skin response to foreign-protein-induced fever is measured. This test is potentially dangerous, as are those using spinal anaesthesia. The authors favour

the test of Morton and Scott, which utilizes anaesthetic block of the posterior tibial nerve and offers an index of arterial occlusion. The skin temperature is taken at five-minute intervals over the areas innervated by the nerve after a 10 c.c. injection of 1 per cent. novocain. The occlusion index is a function of the difference between the temperature reached in normals (30·5° C.) and that observed in the patient. If the skin temperature rises above this level, the disturbance is considered as one of vasospasm. If there is little or no rise in temperature, obliteration of some degree is likely. If the skin temperature rises but does not reach the critical level, both components of vascular disease are present.

The authors believe that this is a good test, but feel that the causes of vasospasm are not limited to the ganglion and periarterial nerve regulatory system but are found also in the intramural autonomic regulating system of the vessel. They therefore studied the effect on skin temperature of block at the ganglion, the intramural site, singly and combined (with novocain for the former and tubocurarine for the latter). In patients with thromboangiitis obliterans and Raynaud's disease, results indicated that the theory presented by the authors is valid, but they stress the fact that this is only a preliminary report and that further studies will be performed.

The Effects of Short Wave Diathermy on Bone Repair. WILLIAM J. HUTCHINSON and BILLIE D. BURDEAUX, Jr. *J. Bone Jt Surg.*, January, 1951, xxxiii-A, 155.

The authors found that repeated clinical doses of diathermy caused a delay in the healing of fractures in rabbits and the union of bone grafts in dogs. New bone formation and callus were of poor structural quality. It appeared that the delay in bone repair was due to the delay in the formation of osteoid tissue and not to a delay in the mechanism of calcification of this tissue. The application of diathermy inhibited the formation of osteoporosis in bone grafts and fractures. The authors believe that this delay was due to decreased vascularity, which was noted in all treated dogs. It was noted that continued use of diathermy in clinical doses caused oedema of the skin, subcutaneous tissues, and muscles in rabbits; and a marked delay in the healing of surgical wounds in dogs and rabbits.

Les Micro-ondes en Électrothérapie. MARIANNE MIRAULT. *Praxis*, October 26th, 1950, xxxix, 927.

Microwave diathermy (Raytheon) was applied to 44 arthritics in courses of 6 to 10 sessions with relief of pain in 18 and partial relief in 36. Results were almost as good in 23 patients with sciatica. The author, who did her work at the physical medicine department of the Geneva Cantonal Hospital, points out that the patient experiences a more agreeable heat penetration with microwaves than with short waves. Her clinical work was preceded by many experiments on animal tissues and phantoms, all of which are described in sufficient detail to be worthy of the attention of all interested in the physiological aspects of this form of diathermy.

Book Review

Synchronous Activity in Normal and Atrophic Muscle. F. BUCHTHAL and A. MADSEN. *J. Neurophysiol.*, 1950, ii, 425.

Previously the authors have shown that motor-unit activity in various parts of a muscle is asynchronous in the normal muscle and in cases of peripheral nerve involvement, while it is synchronous in poliomyelitis and other anterior horn cell involvement. Though these facts were corroborated by other workers, their interpretation gave rise to controversy. It was pointed out that the synchronized record might be due to recording from the same motor unit or to amplifier leak transmitting the same impulse to the other channel.

In the present investigation the authors have not only ensured complete independence of electrodes, amplifier, and recording systems, but have also measured quantitatively the degree of synchronization. Result: "The quantitative measurement of synchronous activity in muscle during sustained slight effort, when leading off with two random leads from different regions of the muscle, have shown that the incidence of synchronization is: (1) 20 per cent. in normal muscle, (2) of the same magnitude or less in muscles with atrophies of peripheral origin, (3) 60 per cent. in muscles with atrophy of central origin."

BOOK REVIEW

The 1950 Year Book of Physical Medicine and Rehabilitation. Edited by FRANK H. KRUSEN, M.D. Chicago: Year Book Publishers Inc. Pp. 328. 40s.

The Year Book of Physical Medicine and Rehabilitation needs little introduction to physical medicine specialists in this country.

From 1938 to 1947 it was edited by Dr. Richard Kovacs, whose death last year was a great loss to the specialty both in England and in America. No "Year Book" appeared in 1948, but in 1949 it reappeared with its present enlarged title under the editorship of Drs. F. Krusen and H. Rusk. This edition contained abstracts of 242 articles and quickly found popularity as a means by which busy practitioners could familiarize themselves with current work being carried out in this rapidly expanding field of medicine.

The present edition contains abstracts of 282 articles from the world literature which were published in the period from December, 1949, to January, 1951. The editor has carefully selected articles representing all branches of the subject. Throughout the book there are editorial comments on 32 of the articles abstracted. These comments are not of great help to readers, who will undoubtedly study the original articles of interest to them and form their own opinion of the importance of the work.

The 1950 Year Book should find a place beside the previous editions in the library of all specialists in physical medicine.

A. T. RICHARDSON.

[*Photograph by St. Thomas's Hospital Photographic Department*

CEREMONIAL LAMP
presented to the International Federation of Physical Medicine by Lord Horder